

LXVIII.—*Australian Entomophytes, or Entomogenous Fungi, and some Account of their Insect-Hosts.* By ARTHUR SIDNEY OLLIFF, Government Entomologist New South Wales, Fellow Ent. Soc. London, Life-Member Ent. Soc. France*.

THE Entomophytes, or Entomogenous Fungi, a remarkable group of parasitic plants which live upon and at the expense of various insects, appear to attain their highest development in Australia, Tasmania, and New Zealand. They may be said to be more or less familiar objects to the tourist, to whom dried but seldom perfect specimens are offered for a few pence, and for whose benefit wonderful stories are related as to their origin. At many of the smaller hostelrys bundles of specimens may be seen ready for the curiosity-seeker; and others are commonly to be obtained from the guides, both white and Maori, in the holiday resorts, especially in the hot-lakes district of Rotorua. These travellers' tales, to some of which we have alluded in detail, have a curious interest of their own, and are by no means confined to the casual observer. They have received currency even at the hands of entomologists and botanists, from whom some hesitation might have been expected in accepting the wild statements made by persons entirely ignorant of the habits and structure of both insects and fungi. It is singular that certain obviously erroneous statements regarding the identity of the hosts upon which these parasitic fungi thrive (although long since corrected by competent observers resident in the countries where the Entomophytes occur) should recur again and again in books of travel and in the writings of systematic entomologists. The worse offenders in this respect, as an examination of the literature of the subject will show, are the lepidopterists, especially those who confine themselves, with a mere pretence of an examination of structural characters, to describing the wing-markings and colouring of such specimens as come before them, a class from which we, in Australia, are unhappily not entirely free. Strangely enough, when other workers holding different views as to the value of the so-called species, established by these describers by methods which can only be compared to those employed in matching pieces of floor-cloth, find it desirable to combine or to disregard these alleged species, it is this very class of lepidopterists who

* From a separate pamphlet issued by the Department of Agriculture, New South Wales, for which we are indebted to the Author.

are loudest in their talk of the necessity for careful breeding of the insects and the observation of their habits and transformations, although wholly disregarding these points themselves. Truly where there is most noise there is least hurt, and it is not to this class of worker that we look for reliable information.

The first, and to this day (from the entomological point of view) the most complete, account of these insect-fungi was issued in 1858 by the late George Robert Gray, Assistant Keeper of the Zoological Department of the British Museum*. This memoir was privately printed, and bears only the writer's initials; but as it has had a tolerably wide circulation, and can be obtained from natural-history booksellers without much difficulty, it may be regarded, for all practical purposes, as having been duly published. It contains a very complete account of all the insects known to the author as being hosts of Entomophytes, or Entomogenous Fungi, and is the most important and original contribution on the subject that has yet appeared. The conspicuous and well-known group of fungi (*Cordyceps*) affecting the larvæ and pupæ of root-eating insects (the Australian species of which are the special subject of the present paper) are dealt with at considerable length; and the observations and conclusions regarding them, except in one particular to be noticed presently, may be accepted as accurate and reliable.

Thirty-four years later, in 1892, a more popular treatise on these parasitic fungi was published by Dr. M. C. Cooke †. In this handy and inexpensive volume, which is issued under the auspices of the Society for Promoting Christian Knowledge, will be found an excellent summary of all that was known of the Entomophytes, and it has a special value as coming from a recognized authority on the larger fungi. For the ludicrous title of the book we believe Dr. Cooke is not responsible. Presumably it is an inspiration of some luminary in the editorial office of the Society for Promoting Christian Knowledge, who, in striving after a popular designation, has succeeded in wholly hiding the subject of the book. It is almost needless to say that none of these fungi, or the insects upon which they live, have any connexion with worms; and

* Notices of Insects that are known to form the bases of Fungoid Parasites, by G. R. G.: pp. 22, with 5 plates. 4to, London (privately printed), 1858.

† 'Vegetable Wasps and Plant-Worms—a popular history of Entomogenous Fungi, or Fungi parasitic upon Insects,' by M. C. Cooke: pp. 354, with four plates and woodcuts. London, 1892. Here quoted as Hist. Ent. Fungi.

that if the term "plant-worm" has any meaning it should be applied to those minute eel-like worms, properly called Nematodes, which are the cause of numerous plant-diseases. In this work, as the author points out, a free use has been made of Gray's observations, and, indeed, as far as the larger species, which more particularly interest us, are concerned, Dr. Cooke's remarks are almost entirely based on the work of Gray. The whole subject, however, and the questions of the origin, habits, and mode of growth of these curious fungi, must obviously be investigated by the entomologist as well as the botanist before satisfactory conclusions can be arrived at; and it is from the botanist's point of view mainly that Dr. Cooke's observations have a special value. The classification put forward by him is here adopted, and the characters upon which the genus *Cordyceps* has been subdivided (the name given by Fries to the species which live as parasites on root-eating and truly subterranean insects) are taken from his work.

One of the fancy stories in regard to the origin of these fungi which has gained wide currency is that the seeds of the rata-tree (*Metrosideros robusta*) are swallowed by the caterpillar, that they then germinate, kill the caterpillar, and grow in the ordinary way. Some, indeed, are so firmly convinced that these vegetable caterpillars are the veritable roots of the trees, that instances have been known where they have been deliberately planted in the confident belief that a row of rata-trees would result. Another singular and equally erroneous belief is that the sweet-potato (*Convolvulus batatus*) may be grown in a similar way, a superstition which has probably arisen from the fact that the caterpillars of the large convolvulus hawk-moth (*Protoparce* or *Sphinx convolvuli*, Linn.) have, by many ill-informed writers, been supposed to be the hosts of these fungi. This supposition, as far as I have been able to ascertain, has not a particle of evidence to support it, although it has gained considerable credence, particularly from observers in the early part of the century.

According to Pereira* a Chinese species (*Cordyceps sinensis*, Berk.) is used for medicinal purposes. He states that it is "used only in the Emperor's palace, as a strengthening and renovating substance, and is supposed to possess properties similar to those ascribed to ginseng †. It is recommended in cases where the powers or the system have been reduced by over-exertion or sickness. A duck is stuffed with five drachms of the fungus, and the bird roasted by a slow fire.

* Quoted by Gray, 'Notices of Insects, &c.,' p. 12.

† Another Chinese medicine.

The virtue of the fungus is supposed to pass into the flesh of the bird, which is to be eaten twice daily for eight or ten days." Unless it is to be supposed that the virtue is confined to those found in Chinese soil, here is a hint for the numerous Mongols in our midst.

Having referred to the old error that the hosts of the various species of *Cordyceps* are the caterpillars of hawk-moths of the family Sphingidæ, we have to notice another and more widely spread delusion with regard to the identity of their hosts which is equally erroneous. This is that the hosts are the larvæ of the large lignivorous Lepidoptera of the family Hepialidæ, known as *Charagia* or *Ænetus*; and the larvæ of certain species of Cossidæ (*Endoxyla*, *Zeuzera*, &c.), which are also wood-eaters. The larvæ of these insects, like those of the gigantic ghost-moth or bent-wing moth (*Zelotypia Stacyi*, Sc.), are lignivorous, living within the stems and branches of the various native trees and shrubs; and it is obvious that it would be impossible for large and highly developed fungi, such as *Cordyceps*, which are sometimes of large dimensions and which are frequently found growing at right angles to the axis of the body of their host, to grow within the narrow limits of the burrows made by these larvæ within their food-plants. With whom the mistake of associating the hosts with *Charagia* originated I have not been able to ascertain; but the error is an old one, as it occurs in the late Dr. George Bennett's 'Gatherings of a Naturalist in Australasia' * and in Gray's 'Notices,' &c., where the male of *Charagia virescens*, Walk. † (said by him to be the perfect stage of the host of the New Zealand fungus *Cordyceps larvarum*, Westw.), is figured; and the error recurs, although long since corrected, in the writings of Butler, Buchanan White, Steele, and Tisdall. As long ago as 1864 the late Mr. A. W. Scott ‡ corrected the error into which Dr. Bennett had fallen, and indicated the true hosts of the *Cordyceps*; but his observations appear to have been overlooked by subsequent writers. In treating of the genus *Pielus* Mr. Scott says:—"We are induced, as being applicable to the matter now in hand, to offer a few observations respecting those Australasian Lepidopterous caterpillars afflicted by *Sphæria* (*Cordyceps*) which have come under our notice, conceiving that this subject has hitherto been treated more in a botanical light than the one interesting to the entomologist; and to do so more effectually it is necessary to exhibit clear outlines of

* P. 288 (1860).

† *Charagia rubrovirens*, Walk., is the female of this moth.

‡ 'Australian Lepidoptera and their Transformations,' pp. 5 and 12.

some of the larvæ with which we are acquainted. By comparing these with the one similarly affected which we obtained here, and also with the delineation on the plate of the living larvæ, together with the appended observations of several writers, a fair conclusion can be arrived at respecting the genus of moth, which, in its two preparatory stages, is liable to the fatal attacks of this fungus. In order, therefore, to carry out the necessary comparison, we copy a lignified larva found at Barrabool Hills, Victoria, and the well-known New-Zealand species. To these we have added sketches of one obtained near Sydney by Mr. Shepherd, and another by ourselves at the Hunter River." Our author then proceeds to summarize the observations of Mr. W. H. Hawkes on *Cordyceps Hawkesii* found at Launceston, Tasmania; and the observations of Mr. John Allen and the Rev. R. Taylor on *Cordyceps Taylora* from Yass, New South Wales. In each case he concludes that the host is the caterpillar of a species of *Pielus*, and, after noting that in the case of the New Zealand form *Cordyceps larvarum*, the host has been incorrectly identified with the larvæ of *Charagia* by Hooker, Dieffenbach, Doubleday, and Taylor, he adds:—"We think it probable that the stems and trunks of the *Metrosideros* furnish sustenance for the larvæ of the *Charagia virescens*; but these live and undergo their metamorphoses within the wood, effectually protected against injury from this particular fungus; and it is equally probable that the external portions of the finer roots of the same or neighbouring plants afford nutriment to the larvæ of such genera as pass their lives wholly in the earth, a state of existence which would render them exposed to the attacks of the *Sphæria* (*Cordyceps*)."

In my opinion we have in these remarks the truth of the matter, and I am inclined to go even further, and to assert that all the larger fungi of the genus *Cordyceps* live upon and at the expense of subterranean larvæ and pupæ. In support of this assertion I would point to the fact that all the bulky species of which the hosts are definitely known have been found on root-feeding insects. As instances I need only cite the Dynastidæ, Melolonthidæ, Elateridæ, and Lucanidæ amongst the beetles, *Cicada* amongst the Homoptera, and *Pielus* and *Trictena* amongst the moths. In all these cases the hosts are subterranean, and it follows that it is idle to speak of any connection between these parasitic fungi and the larvæ of wood-boring or foliage-eating and free-living insects. The best-known and the most abundant species are found on the early stages—larvæ and pupæ—of *Lepidoderma*, *Lepidiota*,

Rhyssonotus, *Cicada*, *Pielus*, and *Trictena*, all of which live underground at the roots of plants.

For an account of the general structure and development of the entomogenous fungi we cannot do better than turn to the writings of Dr. Cooke. This writer* says, "there are four groups under which the fungi parasitic upon insects would primarily arrange themselves, and these, in the order of their importance, would be: first, the ascigerous or *Cordyceps* group, which have mostly a fleshy stroma, a club-like shape, and sporidia contained in asci, including also those imperfect forms or conidial states which belong or are allied to *Isaria*. . . . The first group consists of . . . entomogenous species, to which at first the generic name of *Clavaria* was applied, until their structure and fructification were ascertained, but which were afterwards transferred to the large genus *Sphæria*, on account of their possessing the cells called perithecia, in which the sporidia were developed, enclosed in long delicate sacs or asci. When a division of *Sphæria* took place subsequently a new genus, termed *Cordyceps*, was characterized, to which the entomogenous species, with some few others, were assigned, on account of their fleshy vertical stroma and perithecia, with long filiform sporidia.

"The general and typical form in *Cordyceps* is a somewhat club-shaped erect body, sometimes only a few millimetres and sometimes several inches in height, with a naked, sterile, solid stem, attached by threads of mycelium, and a thicker head, globose, oval, or elongated, which is covered on all sides with nearly globose perithecia, immersed in the substance, and only visible externally by their dot-like mouths or orifices. In a few instances the perithecia are only partially immersed or nearly free, but such instances are rare. At first the perithecia contain only a minute drop of grumous gelatin, but finally this is differentiated into very long cylindrical asci, with a thin membrane, each containing eight long thread-like sporidia, which are commonly nucleate, then septate, breaking up finally into separate joints, each of which is a reproductive unit.

"The vegetative portion, or mycelium, at the base pervades the body of the host-insect, commencing in many instances during life, and at length absorbing the whole interior, converting it into a fungoid mass. The external stroma, constituting the fungus proper, notwithstanding all that has been written to the contrary, is not developed until the whole interior is absorbed, and consequently the insect is dead."

* Hist. Ent. Fungi, p. 1.

This quotation will serve to answer the question often asked in this country as to the truth of the statement that these large parasitic species of *Cordyceps* are found on living caterpillars. It may safely be asserted that they are not; after the germination of the spores, which, I believe, usually occurs in the stomach and intestines, the host-insect quickly dies, and life is certainly extinct long before the stem and other external parts of the fungus are developed.

[This is followed by a synopsis of the species, with descriptions of several new ones, accompanied with four Plates, to which we must refer the reader.—W. F.]

BIBLIOGRAPHICAL NOTICE.

Catalogue of the Marine Mollusks of Japan. By HENRY A. PILSBRY. Svo. Frederick Stearns, Detroit; Kegan Paul, Trench, Trübner, & Co., London, 1895.

PROBABLY more attention has been bestowed upon the marine Molluscan fauna of Japan than upon that of any country, with the exception of Europe, N. America, and some of the British colonies. Within the last thirty-four years two more or less complete catalogues of the known forms were issued by the late Dr. W. Dunker, three very valuable and beautifully illustrated quarto volumes were published by the late Dr. C. E. Lischke, and an enormous number of genera and species were described by Mr. A. Adams from material which he himself collected. In addition, very numerous and important papers have appeared in various journals, and very many species have been described in monographic works and in the reports of the 'Samarang,' 'Challenger,' and other voyages.

The volume before us is the latest contribution to our knowledge of this fauna. It resulted "from the research incidental to the identification of the Mollusea procured by Mr. Frederick Stearns (the publisher) during two visits to Japan."

It consists of a few prefatory remarks by the author, a short introduction by Mr. Stearns, a list of the principal works quoted, and 196 pages of text, containing the list of species, with references and descriptions of about thirty new ones, illustrated by eleven excellent plates.

The whole of the text is not, however, devoted to the marine mollusks, as might be inferred from the title of the work. Only 154 pages have reference to that part of the Japanese fauna, the remainder containing two appendices, respectively on the "Land